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MEASURING OIL RESERVES BY INJECTED GAS

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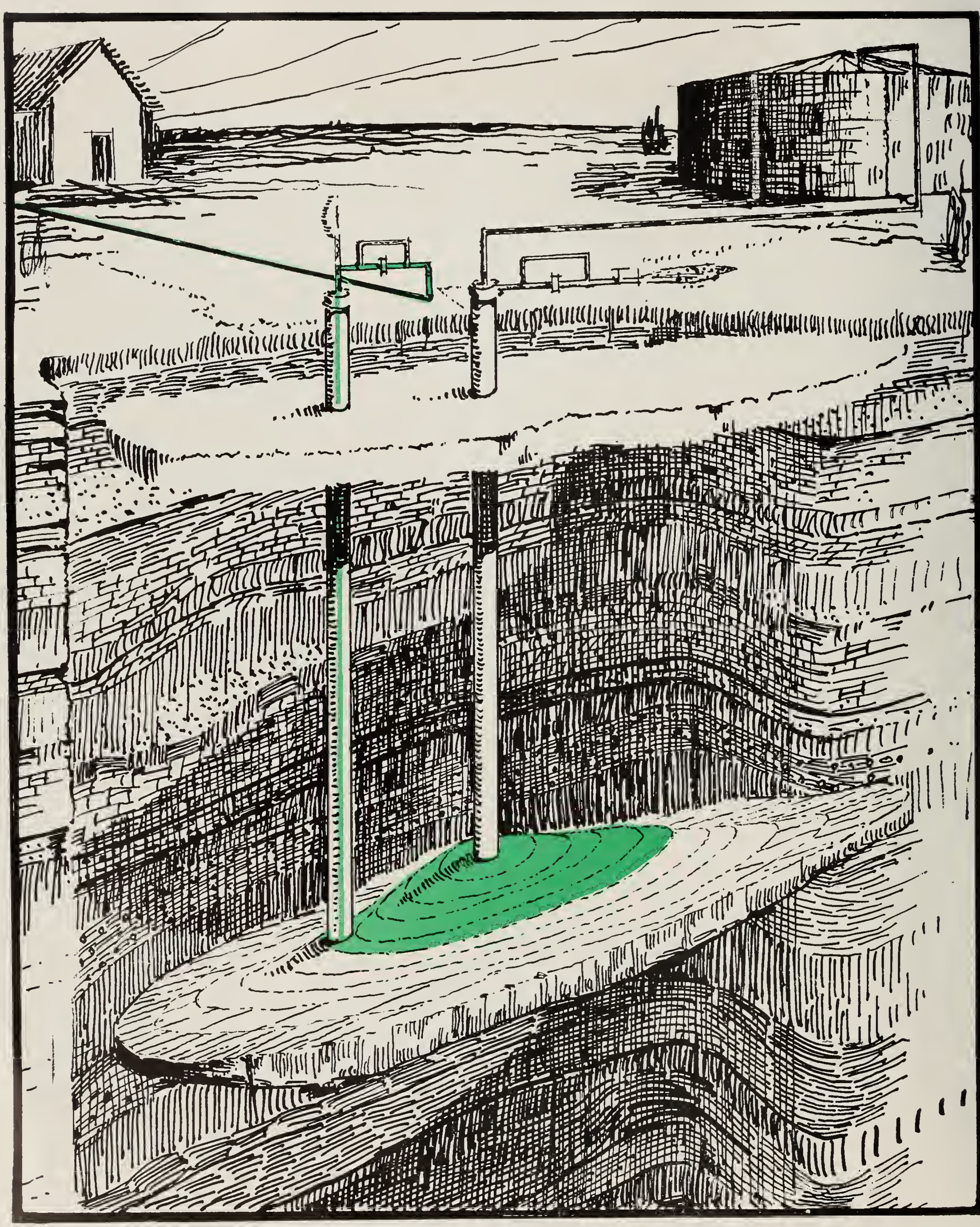

FIGURE 3

Perspective drawing of oil field showing connections for gas injection.

Measuring Oil Reserves by Injected Gas

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PARTLY DEPLETED volumetric reservoirs are evaluated through calculations hinging on the shrinkage of the oil due to loss of dissolved gas as determined early in the life of the producing field. Where no water drive is present, and no gas cap existed early in field history, calculations based on injected gas give conservative estimate of residual oil.

THE writer has applied to gas-injection operations on oil sands in Ohio, West Virginia, and Illinois the J. O. Lewis method of raising the over-all pressure on the stratum in order to force gas to traverse its less permeable as well as its more permeable portions. In doing this he has found that pressure may be built up and brought to equilibrium over an entire field in a short time if the sands are highly permeable and the pool of moderate size. These observations led to the idea that the volume of oil remaining in a partially depleted reservoir might be measured by injecting gas.

All virgin oil and gas reservoirs under pressure are bounded laterally by lensing out of the reservoir rock, by impermeable barriers, or by surrounding water-bearing rock. Such reservoirs are completely full of fluids, and the liquids will contain gas in solution. Volumetric reservoirs without gas caps produce their oil by expansion of solution gas. This article is concerned with the measurement of the amount of oil remaining in such volumetric reservoirs after they are partially depleted.

Measurement Process

The process is illustrated in two ways, first by a simple apparatus shown in Figure 1, and second by a simplified diagram of an oil field shown in Figure 2. This field is shown in perspective in Figure 3.

Consider a tank, A (Figure 1), full of oil containing dissolved gas under pressure. The size and shape of the tank are unknown, but the pressure and the amount of dissolved gas per unit volume of oil have been determined. Part of the oil is drawn off from A, collected and measured at B (Figure 1); the pressure is allowed to fall to atmospheric, allowing all the gas dissolved in all the oil to escape from A. The volume of this gas is measured. (The one atmosphere of gas remaining above the oil in the tank is not considered.)

Subtracting the quantity of gas dissolved in the known volume of vented oil in B from the total measured volume of gas, the remainder is the volume of gas that was originally dissolved in the oil remaining in A. Dividing this by the amount of gas originally dissolved in each unit volume of oil gives the quantity of oil remaining in A. In field practice this means that if you have a record of the original pressure and the amount of dissolved gas in a unit volume of oil and measure the vented oil and gas and water you can determine the amount of oil remaining.

Assume that the volume of gas dissolved in each barrel of oil in A is found to be 500 cubic feet, and the shrinkage of the oil from maximum to minimum pressure is 20 percent.

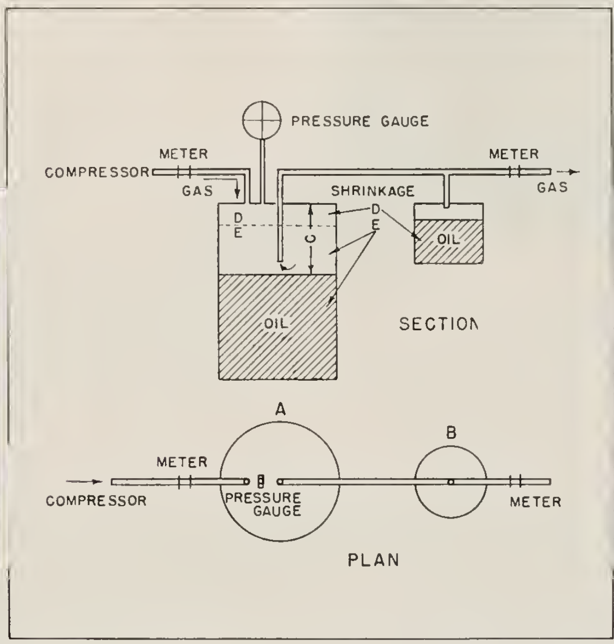
If the volume of oil in B is four-fifths of a barrel and the total volume of gas liberated from A is 5000 cubic feet, then the oil in B will account for 500 cubic feet, and the difference between 500 cubic feet and 5000 cubic feet or 4500 cubic feet is the volume of gas which has been liberated from the oil remaining in A. Since each barrel of oil in A originally dissolved 500 cubic feet of gas and the shrinkage on the liberation of this gas is 20 percent, then there remain nine barrels minus 20 percent or 7.2 barrels of oil in A.

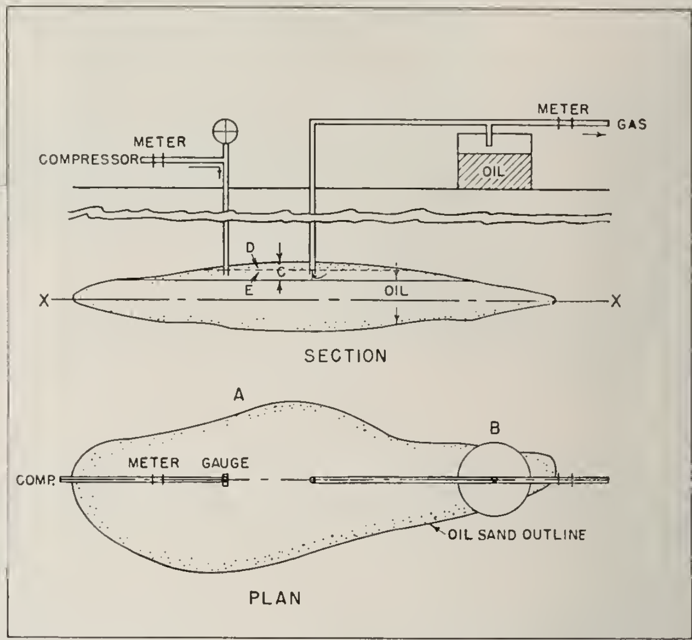
Boyles Law Used

Next, the same procedure, as described above, is repeated but with no measurement of the escaped gas. The problem is the same, namely, to find the volume of oil remaining in A. The space above the oil in A is the sum of the amount of oil removed, shown at B, and the shrinkage of all the oil due to the loss of all the gas. This space is then measured according to Boyles law by pumping in a known volume of gas, allowing the pressure to equalize and noting the pressure to which it raises the reservoir. As shown in Figure 1, this gas will come to equilibrium pressure immediately. In the field, gas should be introduced through many wells. Figure 2 is a simplified diagram showing one injection well. The time required to attain equilibrium will depend on the permeability of the sand and the number of injection wells. The degree to which the method is practical in the field will depend largely on the degree of permeability of the producing strata and the size of the pool. In highly permeable strata, such as in the Johnsonville pool, it would require only a short time to raise the pressure in the reservoir and bring it to equilibrium.

From the space above the oil at A in Figure 1, deduct the volume of oil B and the shrinkage of this oil due to loss of gas. The remainder is the shrinkage of the oil remaining in A. Since this shrinkage is known to be 20 percent, the volume of this oil is readily figured as four times the amount of this shrinkage.

The method for measuring shrinkage of the oil by injecting a known volume of gas and observing the resulting equi-





OIL RESERVES MEASURED BY GAS INJECTION

FIGURE 1.

FIGURE 2.

librium pressure may be used to determine the amount of oil remaining in a partially depleted oil reservoir under the following conditions:

1. When the reservoir is volumetric. Such pools are common in the Cow Run sand in West Virginia and in the McClosky lime in Illinois.
2. When pressure, cubic feet of dissolved gas per barrel of oil at the beginning of production, and shrinkage factor have been determined.
3. When total oil and water produced have been recorded.
4. When the sands are highly permeable.
5. When the pool is of moderate size.

Unknown Volume

In the past it has been the common practice in many areas to produce solution gas without metering it so that its volume is unknown. Such a condition is assumed in the following description of a procedure to determine the quantity of oil remaining in a partially depleted reservoir.

Let x = original oil in field in bbls. total (gas-free basis).

a = oil removed from field in bbls. (gas-free basis).

s = the shrinkage of the oil due to loss of dissolved gas (fraction of original volume).

v = original oil in field in bbls. (before gas loss).

sv = shrinkage in bbls. (for both oil removed and residual oil).

b = volume of void in field calculated from volume of injected gas required to build up a stated pressure.

Then we can see that

$$b = a + sv$$

or

$$v = \frac{b - a}{s}$$

$$x = v - sv$$

$$x - a = \text{residual oil}$$

This calculation requires, primarily, a good measured value for s. It assumes that when gas is injected into the field to determine b, a negligible amount of this gas dissolves in the residual oil. Since the measuring pressure is low and the time of contact of gas and oil is very short, especially in highly permeable sands, this assumption is justified. If conditions are such that a considerable amount of gas is dissolved during this process it may be tested and a proper allowance made for it in the calculations.

Interstitial water is present in almost every reservoir but since the solubility of gas in water is a small fraction of its solubility in oil, it is believed that the effect of interstitial water is essentially only to reduce the void space so that for the purpose of this procedure water may be considered part of the rock. If there is substantial encroachment of water this procedure is not applicable.

If there is no record of original pressure, it is fairly safe to assume that in most areas it approximates hydrostatic pressure for the depth of the reservoir. If there is no record of the amount of gas originally dissolved per barrel of oil, laboratory tests may be made to determine the solubility of similar gas in that particular oil at the original reservoir pressure and temperature. If the oil in the reservoir was not completely saturated, then the error in calculating the amount of remaining oil is on the conservative side.

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